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ELECTRIC FIELD STRUCTURE OF LARGE THUNDERSTORM COMPLEXES IN THE VICINITY OF CAPE CANAVERAL

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1. INTRODUCTION

Several instrumented aircraft were used to make coordinated measurements in and around central Florida thunderstorms during the mid 1960's. Recently it has been possible to improve some of the techniques for analysis of the electric field analog records acquired during this program so that fairly accurate field component values can be related to other aspects of storm structure. The flight of 9 August 1965 to be discussed presented considerable difficulties for the C-130 and U-2 aircraft involved with regard to avoidance of thunderstorm turbulence and lightning activity because of wide-spread convective activity between Cape Canaveral and Orlando. A portion of the data from this day's flight activity is presented to indicate the conditions that can be encountered in and around large thunderstorm complexes in the vicinity of the Cape.

2. DISCUSSION

The radar PPI echo pattern measured at 1338 EST by the Tampa WSR-57 10 cm radar during the initial storm area survey by the U-2 aircraft is shown in Fig. 1. An extensive broad line of echoes was located running parallel to the Florida east coast with the newest active cell developments near the western edge about half way between Patrick AFB and Orlando. These cells tended to form another line toward the southwest. Most of the area seen was filled with extensive thick cirrus decks generally concealing the embedded thunderstorm cells. Standard 4/3 earth refraction would indicate the echo cross-section shown is at about the 1 to 2 km height level over the range of 110 to 180 km from the Tampa radar. Cloud bases in the area were at about 1 km. Surface weather observations indicated a mixture of Sc, Cu, Ac, and Ci cloud forms. The inland storms tended to increase in size with little overall motion during the afternoon. A portion of the U-2 flight track is overlaid on the radar map. Flight altitude varied from about 13.5 km over the eastern storm to about 15.5 km in the vicinity of the active western cells. Two separate and very distinct regions of electrical activity as measured from the airplane are shown on the flight track. The separated electric field components are shown in Fig. 2 with the same horizontal distance scale as the

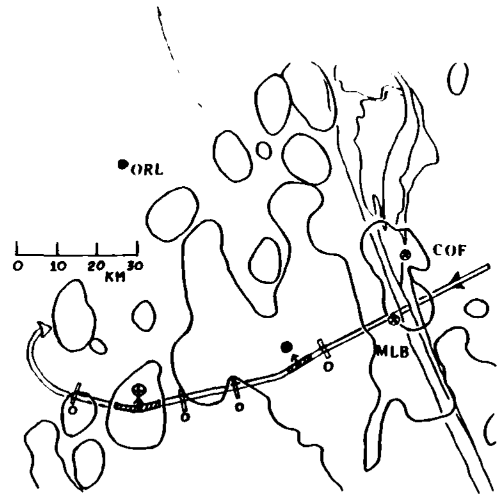

Figure 1. PPI radar cross-section and U-2 flight track.

radar cross-section. A positive Ex component indicates positive excess charge ahead of the aircraft. Positive Ey indicates positive charge to the right of the flight track. Negative Ez denotes positive charge below the aircraft. The aircraft penetrated the upper part of the eastern storm. The trace for Ex indicates a typical pattern for location of charge concentrations, consisting of growth to a maximum field value, rapid nearly linear crossover through zero as nearest approach to the positive charge center is obtained, a field reversal to the opposite sign maximum and final decay of the field to near zero. The Ey trace indicates excess positive charge to the right of the aircraft with the maximum field occurring about the time of the Ex crossover thus confirming the estimate of charge location. The Ez trace appears to indicate excess positive charge above the aircraft initially then followed by a more complex distribution. Some limiting of the amplifier for this data occurred during the interval indicated as L below the trace. This may have an effect on the separation of the Ez component from the composite sensor signal during this time period. A large region of minimal field activity except for distant lightning field changes is seen to separate the eastern and western active convective zones encountered on this track. The western storm was located over Lake Kissimmee and had active convective turrets extending to above

15 km. The pilot maintained visual flight about 500 m above and to the side of the main turret on this pass. The quasi-steady field pattern associated with the main excess positive charge centroid is discernable through the number of lightning field change and recovery events.

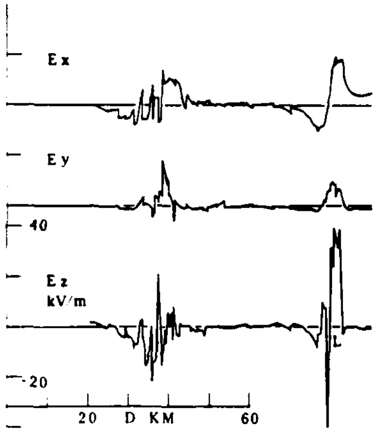

Figure 2. U-2 electric field components over two storms.

The instrumentation included a 8 to 13 micrometer infrared downward-looking radiometer with a 2 degree field of view. Figure 3 indicates the cloud top profile for this pass obtained by using an optically thick cloud model and transforming the infrared temperature profile to a height profile through use of the Cape radiosonde data. It is seen that continuous cloud cover over a 95 km path was encountered with about 65 km of cloud extending to above 13 km height. The electric field component along the flight direction is shown above the IR profile to indicate the extent of the electrically active regions in this large complex. The storm top penetration of the eastern storm is shown in expanded scale in Fig. 4. The main charge distribution is seen to extend through an approximate 4 km diameter. The fine structure in a portion of the trace may be associated with corona discharge events on the aircraft.

3. SUMMARY

Extensive measurements of the electric field, radar, thermal, and draft structure of these storm complexes were made by the three test aircraft over a period of about 1 and 1/2 hours covering portions of the 7 to 16 km height range. Later afternoon storm penetration flights at 4.6 and 3 km altitude were conducted by the F-100F aircraft. The other U-2 passes over the storms had generally similar field structure to that illustrated. The F-100F data during penetrations was generally more complex than the overflight data. General results of the day's activity are contained in Tables 1-3. The horizontal and vertical field components in the storms were found to be larger at the lower altitudes. However small very intense field re[illegible]s were occassionally found at high altitude as evidenced by the 120 kV/m peak on pass 3 of the first flight. It is also of interest to note that the largest field change associated with a lightning strike to the F-100F occurred at high altitude. This was in the middle of the Lake Kissimmee storm echo about 10 minutes after the overflight data shown in Fig's. 1-4.

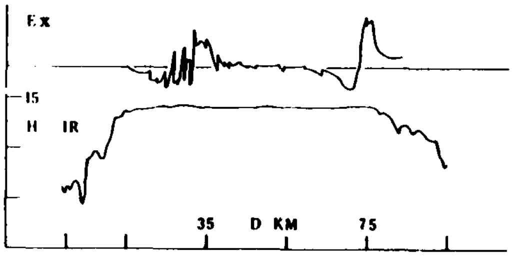

Figure 3. Height profile and electric field across storms.

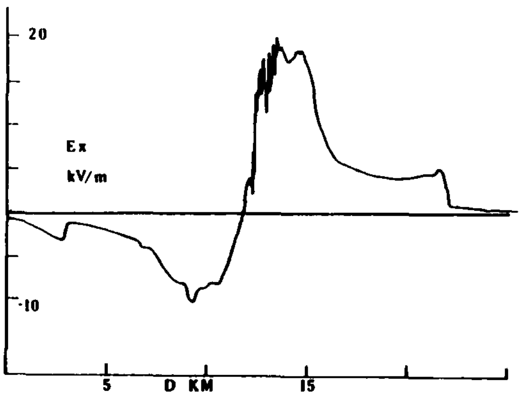

Figure 4. Longitudinal component of field during storm top penetration at -66°C.

TABLE 1. Summary of U-2 Data 9 August

Time EST	IR Top T °C	Field Max kV/m $\lvert E_H \rvert$	$\lvert E_z \rvert$	Dimension of Field Dist. KM
1338-42	-66.5	19.6	40.0*	30
42-44	-68.0	17.5	21.5	52
48-49	-66.0	9.2	8.7	33
50-52	-65.5	7.0	16.3	33
57-59	-63.0	5.4	11.8	32
1413-15	-63.0	9.3	16.9	51
18-20	-61.0	7.8	14.3	45
21-23	-60.0	1.7	3.9	32
26-28	-60.0	11.4	45.0*	50
31-33	-59.0	5.1	9.6	50
38-39	-59.0	9.0	12.2	55

*Denotes cloud top penetration.

TABLE 2. Summary of F100 Data
9 Aug 8.8 km Pressure Altitude

Pass	Field Maximum on Pass (kV/m) Max $\lvert E_y \rvert$	Max $\lvert E_z \rvert$	Lightning Strike ΔE	Mean Free Air Temp T-°C	Temp Perturbation °C
1	25.5	52.5	-195.0	-29.5	6.2
2	24.0	55.0	-	-	-
3	25.0	120.0	-	-	-
4	24.0	50.0	-	-29.5	5.5
5	21.5	45.0	-	-30	1.7
6	23.5	45.0	-	-30	3.1
Other Storm Areas					
3C	23.5	40.0	-	-	-
4A	24.5	40.0	-	-30	3.5
4C	24.0	45.0	-	-30	2.3
7	24.0	35.0	-	-30.5	2.9

TABLE 3. Summary of F100 Data
9 Aug 4.6 km and 3.0 km Pressure Altitude

Pass	Field Maximum on Pass (kV/m) Max $\lvert E_y \rvert$	Max $\lvert E_z \rvert$	Lightning Strike ΔE	Max Acc.	Min Acc.
1	40.5	105.0	-180.0	1.3	0.5
2	38.5	-	-	1.3	0.4
3	44.5	115.0	-	1.3	0.7
4	44.0	115.0	-	1.3	0.5
5	42.0	65.0	-175.0	1.4	0.7
6	42.0	85.0	-	1.3	0.6
7	43.5	67.5	-	1.3	0.8
8	36.0	45.0	-	1.4	0.6

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Extensive measurements of electric field components, radar cross-sections, thermal, and draft structure were made in and around large thunderstorms in central Florida during a previous flight program. Recent advances in analysis of the in-flight electric field data have been used to locate regions of localized charge concentrations in the large storm systems, thus providing guidance for possible real-time avoidance of zones of aircraft lightning strike hazard.

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